

 GLAST LAT TECHNICAL NOTE	Document # LAT-TD-00235-01	Date Effective 6 July 2001
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	Subsystem/Office Calorimeter Subsystem	
Document Title Calorimeter Failure Modes and Mitigation		

Gamma-ray Large Area Space Telescope (GLAST)
Large Area Telescope (LAT)
Calorimeter Failure Modes and Mitigation

DOCUMENT APPROVAL

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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes

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1 Purpose

This document summarizes failure modes and mitigations for various components of the calorimeter.

2 Scope

This document contains a broad list of failure modes and possible mitigating responses, but it is not an exhaustive list. It was prepared with consideration of scientific performance as paramount.

3 Definitions

3.1 Acronyms

AFEE – Analog Front End Electronics Board

GCFE – GLAST Calorimeter Front End ASIC

GCRC – GLAST Calorimeter Readout Controller (digital ASIC)

GLAST – Gamma-ray Large Area Space Telescope

LAT – Large Area Telescope

TBD – To Be Determined

TBR – To Be Resolved

CAL – Calorimeter Detector

TEM – Tower Electronics Module

3.2 Definitions

μsec, μs – Microsecond, 10^{-6} second

Dead Time – Time during which the instrument does not sense and/or record gamma ray events during normal operations..

s, sec – seconds

4 Applicable Documents

Documents that are relevant to the development of the GCFE concept and its requirements include the following:

GLAST00010, “GLAST Science Requirements Document”, P.Michelson and N.Gehrels, eds., July 9, 1999.

LAT-SP-00010, “GLAST LAT Performance Specification”, August 2000

LAT-SS-00018, “LAT CAL Subsystem Specification – Level III Specification”

LAT-SS-00210, “LAT CAL Subsystem Specification – Level IV Specification”

LAT-SS-00088, “Calorimeter Front End ASIC- Conceptual Design”

5 Introduction

The following table lists a number of possible failures within the CAL subsystem, their possible causes or the type of failure, the immediate effect of the failure on the performance of the CAL, possible mitigating responses, the performance of the CAL after the mitigation has transpired, and an “allowable” rate of the specified failure.

Component	Possible cause or Failure type	Effect of failure	Mitigation	Performance after mitigation	Allowable rate
CAL subsystem		No energy measurement. Loss of science.	None	No energy measurement. Loss of science.	None
CAL tower	TEM; power	>1/16 of data lost, CR rejection compromised	None. Modify E algorithms, bkg rejection algorithms.	>1/16 of data lost. CR rejection compromised. Energy measurement compromised.	None
CAL side	TEM i/f failure, cable failure; AFEE failure	~50% loss of measured energy in 48 logs (1/2 tower). Lose longitudinal position information in 48 logs. Lose redundancy in 48 logs. 25% loss of data volume from tower.	Modify E algorithm in ground s/w. Can be automated. Modify CAL-only direction measurements. Modify bkg rejection algorithms?	Resolution in 48 logs degraded to >5%. Lose longitudinal position information in 48 logs. Lose redundancy in 48 logs. 25% loss of data volume from tower.	One side
GCRC (Digital Controller)	Complete failure (power, chip)	~50% loss of measured energy in 12 logs. Lose longitudinal position information in 12 logs. Lose redundancy in 12 logs. 6% loss of data volume from tower.	Modify E algorithm in ground s/w. Can be automated.	Resolution in 12 logs degraded to >5%. Lose longitudinal position information in 12 logs. Lose redundancy. 6% loss of data volume from tower.	8 controllers, i.e. ~3% of CAL log ends.

GCFE chip	Complete failure	~50% loss of measured energy in single log. Lose longitudinal position information in single log. Lose redundancy in single log. Negligible decrease in data volume (i.e. by 32 bits for only those events that should have involved the failed log).	Modify E algorithm in ground s/w. Can be automated.	Resolution in single log degraded to >5%. Lose longitudinal position information in single log. Lose redundancy in single log. Negligible decrease in data volume.	100 chips, i.e. 3% of CAL log ends.
GCFE chip	Failure of zero suppress	Increase data volume by one log (32 bits) for every event.	None?	Increase data volume by one log (32 bits) for every event.	300 chips (i.e. 10% increase in CAL data volume).
GCFE chip	Failure of autoranging	Miscalculated energy in single log?	None? Disable log face in flight?	Miscalculated energy in single log?	
GCFE energy range		~50% loss of measured energy over 1/4 of dynamic range in single log. Reduce redundancy in single log. Bias in auto-ranging in single log. Possible bias in longitudinal position information in single log.	Modify E algorithm in ground s/w. Can be automated.	Small increase in energy uncertainty in single log. Reduce redundancy in single log. Bias in auto-ranging in single log. Possible bias in longitudinal position information in single log.	100 ranges, i.e. ~3% of log ends.
ADC		~50% loss of measured energy in single log. Lose longitudinal position information in single log. Lose redundancy in single log.	Modify E algorithm in ground s/w. Can be automated.	Resolution in single log degraded to >5%. Lose longitudinal position information in single log. Lose redundancy in single log.	100 chips, i.e. ~3% of log ends.
Dual PIN module	Open circuit, no signal	~50% loss of measured energy in single log. Lose longitudinal position information in single log. Lose redundancy in single log.	Modify E algorithm in ground s/w. Can be automated.	Resolution in single log degraded to >5%. Lose longitudinal position information in single log. Lose redundancy in single log.	100 dual PINs, i.e. ~3% of log ends.

Large PIN diode	Open circuit, no signal	~50% loss of measured energy <1.6 GeV in single log. Lose redundancy in single log.	Modify E algorithm in ground s/w. Can be automated.	Degrade longitudinal position information <1.6 GeV in single log.	100 PINs, i.e. ~3% of log ends.
Small PIN diode	Open circuit, no signal	~50% loss of measured energy >1.6 GeV in single log. Lose redundancy >1.6 GeV in single log.	Modify E algorithm in ground s/w. Can be automated.	Resolution in single log degraded to >5% >1.6 GeV. Lose longitudinal position information >1.6 GeV in single log. Lose redundancy >1.6 GeV in single log.	100 PINs, i.e. ~3% of log ends.
Dual PIN module	Loss of bias	Increased noise, decreased resolution in single log.	Raise zero-suppress LLD	Decreased resolution in single log.	100 dual PINs, i.e. ~3% of log ends.
Large PIN diode	Loss of bias	Increased noise, decreased resolution in single log <1.6 GeV.	Raise zero-suppress LLD	Decreased resolution in single log <1.6 GeV.	100 PINs, i.e. ~3% of log ends.
Small PIN diode	Loss of bias	Increased noise, decreased resolution in single log >1.6 GeV.	None	Decreased resolution in single log >1.6 GeV.	100 PINs, i.e. ~3% of log ends.
Dual PIN module	Failed optical bond	~25% loss of measured energy in single log	Recalibrate with GCRs. Modify E algorithm in ground s/w.	Resolution in single log degraded to >TBD%.	100 dual PINs, i.e. ~3% of log ends.
Large PIN diode	Failed optical bond	~25% loss of measured energy <1.6 GeV in single log	Recalibrate with GCRs.	Resolution in single log degraded to >TBD%.	100 PINs, i.e. ~3% of log ends.
Small PIN diode	Failed optical bond	~25% loss of measured energy >1.6 GeV in single log.	Recalibrate with GCRs.	Resolution in single log degraded to >TBD%.	100 PINs, i.e. ~3% of log ends.
Calibration DAC		Degraded E resolution in ½ of tower. Increased uncertainty at high end of HEX1 range.	None, but increased reliance on GCR calibration.	Degraded E resolution in ½ of tower. Increased uncertainty at high end of HEX1 range.	

CAL-LO Trigger, single tower		During I&T: Loss of ability to calibrate tower with muons. During flight: Loss of ability to use CAL-LO to throttle TKR trigger rate. Loss of ability to measure TKR trigger efficiency.	During I&T: Hardware replacement. During flight: None	Loss of ability to use CAL-LO to throttle TKR trigger rate. Loss of ability to measure TKR trigger efficiency.	16 towers? None?
CAL-HI Trigger, single tower		Reduced efficiency of CAL-only triggers. Reduced effective area at high energies.	None.	Reduced efficiency of CAL-only triggers. Reduced effective area at high energies.	
CAL-LO Trigger, single GCRC	Fail in asserted state	Rapid triggering, large data volume. Loss of CAL-LO trigger from several log faces.	Disable trigger from failed GCRC.	Loss of CAL-LO trigger from several log faces.	
CAL-HI Trigger, single GCRC	Fail in asserted state	Rapid triggering, large data volume. Loss of CAL-HI trigger from several log faces.	Disable trigger from failed GCRC.	Loss of CAL-HI trigger from several log faces.	

6 Notes

In the absence of any external definition of what an allowable rate of failure might be, in most cases I have arbitrarily chosen 3% of log faces and computed the number of subsystem elements that number corresponds to. I would assert without proof that a 3% loss of log faces would not degrade the CAL performance below the SRD levels. However, multiple 3% losses – i.e. losses of several of the listed functional elements – will likely be too much.

Other than the redundancy provided by the readout of each log from both faces and of the overlap of energy ranges within the readout of each log face, I have ignored the issue of the existence of redundant systems. Instead I have concentrated on failure of a given functionality, which may require the failure of both a primary and a redundant element

Except as explicitly noted, all failures are assumed to be during flight, or more correctly, after our last ability to modify the hardware prior to launch.

To estimate the loss in resolution from the loss of readout at one log end, I took the typical light attenuation slope to be 1.25% per cm, multiplied by the Moliere radius (90% energy containment) in CsI (~3.5 cm), and defined that to be the 1σ resolution: thus $\sigma = 4.5\%$. (I took it to be one sigma because there are long tails outside the Moliere radius). This is likely an over-estimate.

We need to simulate effects of tower-level failures on energy measurements and background rejection.

Disabling of triggers should be on as fine scale as possible, i.e. the failure of a single GCRC trigger in an asserted state should not require that an entire tower or TEM CAL trigger be disabled.

I have not yet included any discussion of failures in commanding. This must be addressed.